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A source of renewable energy in Malaysia, why biodiesel?

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A B S T R A C T

Recent surge in crude oil price, finite fossil oil resources, and environmental issues all have aroused grave concerns. The world in 2012 consumed up to 12,476.6 million tons oil equivalent and 87% of this energy came from fossil sources. Malaysia has encountered an increase in energy demand following the country's development and economic growth. Currently, biodiesel is one of the main options to replace petroleum-derived diesel. Thanks to its environment friendly properties and almost similar performance with fossil fuels, biodiesel sounds like a promising option. The present paper deals with available renewable energy scenarios and examines alternative energies such as biomass, solar, wind and mini-hydro energy. The purpose of using the new sources of energy is to make sure of availability of reliable and secure supply of energy for the country. The energy demand and supply are also discussed based on source and relation to the country's fuel diversification policy. The study evaluates Malaysia's status quo in energy and biodiesel market, its strengths from economic, social, and environmental viewpoints and the production of biodiesel in the country. Moreover, the country's potentials to become a leading producer of biodiesel are further studied. The concentration in the study is on biodiesel production in Malaysia. The main portion of raw material for producing biodiesel is palm oil as the country is among the largest producers of palm oil at international level. There are optimistic expectations that by developing biodiesel production in the Malaysia, not only will the countries' energy needs be met, but the country will emerge as a role model that paves the path toward more production of biodiesel all around the world.

Contents

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1. Introduction

The challenge of supplying energy has always boggled the mind of policy makers all around the world; one reason is the undeniable dependency of modern humans on energy of required quality and quantity [1]. Recently, great concerns have been aroused due to increase in oil price and shrinking fossil fuel resources. Consequently, renewable energy sources have gained attention as a solution to replace fossil fuels [2]. The huge demand for energy in the developed countries and transportation sector [3] and spread of pollution caused by fossil fuel consumption signals the necessity to develop renewable energy sources with fewer effects on the environment. This powers recent attention of the scientists to look for new sources to replace oil-based fuels. The candidate fuel must be easy to obtain from technical and economic viewpoint, environment friendly, and practically accessible [4]. In spite of the fact that several alternative energy sources such as biomass, sun, mini-hydro, etc., have been found, fossil fuels still constitute the main portion of energy consumption in the world. For instance, oil, natural gas, and coal constituted 77% of world energy source in 2011 (Fig. 1) [3]. The same year experienced 5.7% increase in coal consumption; coal has hit the above average growth rate and experienced the fastest growth rate among non-renewable energy sources. It currently covers 30.3% of world energy consumption, which is a record since 1969 [5].

Global energy consumption in 2012 grew to about 12,476.6 million tons oil equivalent (Mtoe) and around 87% are from fossil fuels [6]. Resources of the fossil fuel are limited (not hydroelectricity and nuclear energy) and with this rate of consumption, in near future there will be no fossil energy resource to use [4,7]. One of the promising options for non-renewable energy, which has drawn a great deal of attention lately, is biodiesel, which exhibits with almost the same properties as petroleum-derived diesel [8]. By definition, biodiesel is a fatty acid methyl or ethyl esters extracted from animal fat or plant oil [9]. In general, by biofuel we refer to different forms of fuel whether in gas or liquid forms, which are obtained from biomass [10]. The main producer of biofuel in the world is North America. Table 1 lists the biofuel production rate on a region basis [5].

According to the statistics, production of biodiesel has shown a steep rising trend in recent years. The annual production of ethanol and biodiesel between 2005 and 2021 is depicted in Fig. 2 [11].

There are expectations of a growth of up to 42 billion litres (BnL) in production of biodiesel by 2021. In recent developments, two main producer countries of palm oil (Indonesia and Malaysia) have prepared refining capacities with flexibility for quick shift to biodiesel production in case the world prices justify export of the fuel [11].

As the leading producers of biodiesel, we may name Canada, the USA, France, Brazil, Indonesia, Malaysia, and Australia [11]. There are speculations that global vegetable oil production may hit 35 million tons (Mt) in 2021, which is a 28% increase compared with 2011. This is higher than previous forecasts, which is because of two perennial oil crops (i.e. palm and coconut oil). About 79% of global vegetable oil production is supplied by Indonesia, Malaysia, China, the EU, The USA, Brazil, and India. Indonesia and Malaysia have plans to emerge as the leading producers of oil production (20% and 14% respectively) by 2021. It is expected that in the coming 10 years total production of palm oil of the two countries will grow by 37% (12 Mt). Consequently, palm oil is expected to constitute about 33% of the world vegetable oil production in 2021. About 2% annual growth of global demand for vegetable oil is forecasted. There are expectations of growth in demand for edible vegetable to be used for biodiesel production up to 30 Mt; this figure represents a 76% raise over the base period and increase of the portion of vegetable oil in production of biodiesel from 12% in 2009–2011 to 16% in 2021 [11]. There has been extensive planning and preparations to increase share of biodiesel in the fuel supply in many countries as shown in Table 2.

A shift of attention to biodiesel as a product for export, instead of a source domestic energy, has been started recently in Malaysia.

2. Energy situation in Malaysia

Furthermore, Asia-Pacific Economic Cooperation (APEC) predicted the total demand for energy will hit the final record of 6248 million ton of oil equivalent (Mtoe) in 2030 – i.e. 40% increase at the annual increase rate of 1.3%. It is expected that Malaysia, a developing country, experiences steeper growth rate of 3.3% between 2005 and 2012 and a bit faster (3.4%) afterward until 2030. To meet the demand for energy source in the growing economy of Malaysia, the country needs more energy sources. In spite of the fact that the country owns the 2nd largest reservoir of oil in Asia Pacific with total reserve of 5.6 billion barrel, Malaysia

Table 1
Biofuels production (thousand tons oil equivalent) [5].

	2005	2010	2011
North America	7612(38.64%)	26226(44.86%)	29,224(49.64%)
Central and South America	8093(41.08%)	17,863(30.56%)	16,129(27.4%)
Europe & Eurasia	3157(16.02%)	10,811(18.49%)	9837(16.71%)
Middle East	–	–	–
Africa	6(0.03%)	29(0.05%)	29(0.05%)
Asia Pacific	834(4.23%)	3528(6.04%)	3649(6.2%)
Total World	19,701(100%)	58,457(100%)	58,868(100%)

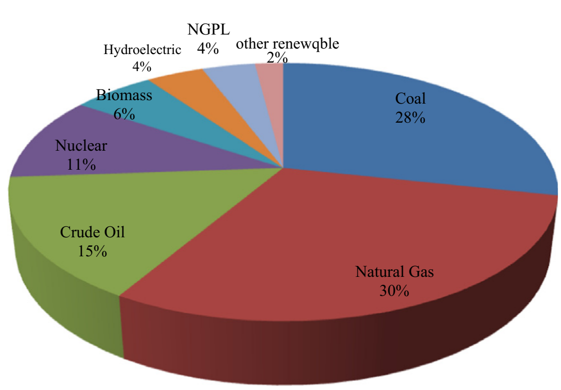


Fig. 1. World primary energy production in 2011.
Source: [3].

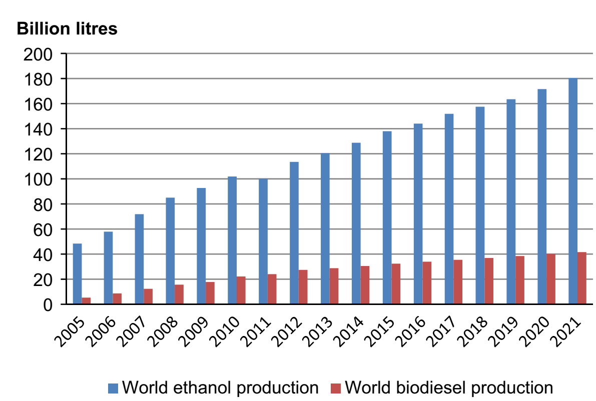


Fig. 2. World annual biodiesel and ethanol production [11].

has come to understand that the oil resources may not meet its demand. With the production level of 2005, the country can rely on its oil reserve for 15 years and gas reserves are expected to be reliable for 29 years. Based on the 2013 analyses of Asia-Pacific Energy Research Center (APERC) the demand in residential and commercial sectors will experience the fastest growth from 2010 to 2035 of 1023 Mtoe or 64%. On the other hand, International freight services will go forward with almost the same rate (up 61%), which shows growing globalized economy. Moreover, national demand for transportation will experience the lowest growth rate, so that energy demand will grow only up to 29%. The increasing number of cars on the streets will be compensated to some extent by development of more efficient vehicles [5,19,20].

Malaysia National Energy Policy of 1979 targets an efficient, safe, reliable, and environment-friendly energy supply in future. It also puts emphasis on necessity of clean and adequate energies for supporting acceleration of economic development [21]. In recent years, comparing with recent primary energy supply, Malaysia's energy consumption has been featured with lower growth rate. Final energy demand and primary energy supply between 1978 and 2011 are pictured in Fig. 3 [22].

Total demand for energy followed an ascending trend from 29,698 thousand tons of oil equivalent (ktoe) in 2000 to 43,501 ktoe in 2011 (Table 3). As the data shows, final energy demand of 2011 experienced 4.9% increase of demand in comparison with that of 2010. The largest portion of demand for energy in 2011 (55.5%) was for petroleum products (derivatives of crude oil); next in the line were electricity (21.2%), natural gas (19.7%), coal and coke (4.0%) [22]. These figures hint relative success of the government's project to attenuate overall dependence on one energy source and shifting the demand to other alternative sources of energy.

In spite of the fact that demand and supply of natural gas increases steadily although slowly, the general energy basket is always reviewed to make sure the energy supply is reliable and secure in long-run. The government has committed itself in the 9th Malaysian Plan (2006–2010) to increase the role of renewable energy sources as supplement to traditional energy source [21].

Although, the growing economy has increased demand for energy, the government tries to ensure implementation of fuel diversification policy. The policy is aimed at attenuating the considerable dependence on oil as the main source of energy in Malaysia.

By tradition, Malaysia relies to a great extent on its agricultural products. The country is known as one of the biggest agricultural products producers in the world. The agricultural economy of Malaysia involves crops cultivation livestock farms and fishery. At any rate, public lifestyle changes, following development of cities and increase of public welfare, have emerged in new nutrition programs, family food supply and consumption patterns [23]. These changes are evident in the population, economic activities (pertinent to economy sectors) and demand for energy, all of which have had positive effects on gross domestic product (GDP) of the country. As reported by the department of statistics, the Malaysian population increased between 2000 and 2010 from 23.495 million to 28.251 [24].

A positive relation was found between growth rate of population and demand for energy. Economy and energy demands grow in parallel and result in changes in energy consumption pattern. The biggest portion of Malaysian economy growth is its services section, which constitutes 51.6% of the total revenue; the next in the list are manufacturing (28.6%), mining and quarrying (8.5%), agriculture (7.5%), construction (2.7), and customs tariffs (1.1%). Moreover, per capital energy consumption has raised from 1.26 toe/person in 2000 to 1.63 toe/person in 2007 and followed a descending trend toward 1.47 toe/person in 2010 [22,23,25]. This hints the government need to understand the necessity to find new energy sources.

There are speculations that energy consumption will reach 971 TWh (83.5 Mtoe) with a trend of 5.4% annual growth up to 2020. The increases in demand is mostly rooted in industrialization and higher demand in manufacturing and transportation sectors [26].

As the table above lists, the maximum demand for energy in 2011 is 43,522 ktoe, the main portion of which has been consumed by transportation sector (39.2%), followed by industries (27.8%), residential and commercial sectors (16.0%), non-energy sector (14.8%) and agriculture(2.1%) [22]. Energy demand for the interval between 1995 and 2011 is listed in Table 4.

Table 2
Short summery of worldwide biofuel current mandate and planned targets [12–18].

Country	Official biofuel targets
Brazil	40% rise in ethanol production, 2005–2010; mandatory blend of 20–25% anhydrous ethanol (E 20–25)with petrol; minimum blending of 5% (B5) biodiesel to diesel by January 2013 20% biodiesel (B20) in fossil fuel by 2015
Canada	5% renewable fuel standard in all Canadian fuel and 2% biodiesel content in diesel fuel by 2012
European Union	10% in 2020 (biofuels); target set by European Commission in January, 2008
UK	5% by 2020 (biofuels, by energy content)
Indonesia	20% biodiesel and 15% ethanol blend in fossil fuel by 2025
India	20% Biodiesel content in diesel fuel by 2012
Malaysia	EnvoDiesel in all fuel stations and industrial sectors from 2008
Thailand	10% replacement of diesel in 2012

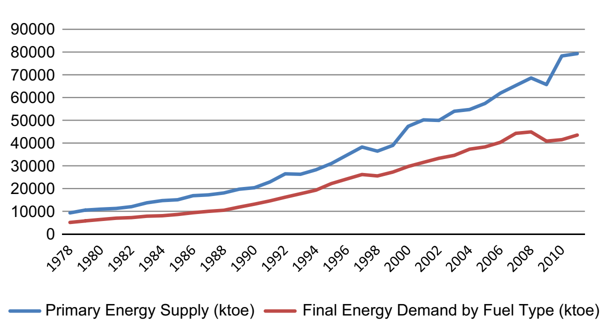


Fig. 3. Malaysia's final energy demand and primary energy supply for 1978–2011 [22].

Table 3
Final energy demand by source in Malaysia, 1980–2011 [22].

	1980	1985	1990	1995	2000	2005	2010	2011
Petroleum products	5550	6656	9825	16,142	19,581	23,012	24,403	23,923
Natural gas	35	515	1093	1935	3863	6981	6254	8578
Electricity	747	1079	1715	3375	5263	6943	8993	9241
Coal and coke	53	362	513	712	991	1348	1826	1759
Total	6385	8612	13,146	22,164	29,698	38,284	41,476	43,501

Table 4
Final energy demand by sectors (ktoe) [22].

	1995	2000	2005	2010	2011
Industrial	8341(37.6%)	11,406(38.4%)	15,492(40.5%)	12,928(31.2%)	12,115(27.8%)
Transport	7827(35.3%)	12,071(40.6%)	15,384(40.2%)	16,828(40.6%)	17,070(39.2%)
Agriculture	446(2.0%)	104(0.4%)	101(0.3%)	1074(2.6%)	916(2.1%)
Non-energy	2994(13.5%)	2250(7.6%)	2173(5.7%)	3696(8.9%)	6438(14.8%)
Residential and commercial	2556(11.5%)	3868(13.0%)	5134(13.4%)	6951(16.8%)	6983(16.0%)
Total	22,164(100%)	29,699(100%)	38,284(100%)	41,477(100%)	43,522(100%)

Table 5
Primary energy supply by source in Malaysia, 1980–2011 [22].

	1980	1985	1990	1995	2000	2005	2010	2011
Petroleum products	8261	9715	12,434	16,769	23,104	24,414	25,008	26,927
Natural gas	2237	3971	5690	11,064	20,194	24,783	36,936	35,740
Electricity	383	1019	915	1540	1560	1313	1577	1867
Coal and coke	53	362	1326	1612	2486	6889	14,777	14,772
Total	10,934	15,067	20,365	30,985	47,344	57,399	78,298	79,306

In spite of the fact that industry sector has recently exceeded other sector; transportation still is a major energy consumer in Malaysia [27,28]. Transportation fills a critical role in globalization and economy. By consuming the main portion of energy sources (39.2%), transportation sector poses threats to the environment while it consumes the limited source of non-renewable energy sources. As suggested by the statistics, around 13.5% of global warming threat comes from transportation sector [22,29]. Crude oil-based fuels supply about 96% of the worldwide energy demand for transportation [30].

An annual increase of 5% in GDP has been predicted by Preliminary Energy Outlook published by Malaysia Energy Center (PTM); however, final energy consumption of the country is forecasted to experience an annual growth of 4.8% from 2000 to 2030. Speculations for the coming 25 years show an increase in energy consumption in transportation by 5.3%, industry by 4.8% and other sectors such as residential, commercial, and agricultural sectors by 5.3%, 4.8%, 4.2% per year respectively [31]. Regarding the supply, there has been an increase from 10,934 ktoe in 1980 to 79,306 ktoe in 2011 (Table 5) [22]. The major portion of energy has been supplied by natural gas (45.1%) crude oil and petroleum products (34.0%), coal and coke (18.6%) and hydro (2.4%) in 2011. In comparison with the data of 2000, a decrease of 14.9% in dependency on oil and petroleum production has been achieved, while that on coal and coke consumption has increased by about 13.3% [22].

Despite the evidences from experimental results that higher mixture of biodiesel (with diesel) brings in higher performance, Malaysian industrial sectors have set their target, for the time being, to apply B5 diesel for their boilers, generators, and machineries. In this regard, all sectors of the industry have been taken into consideration. For example, biodiesel has been found as a good choice by marine industries since, as the boaters have stated, it generates less smock thanks to non-toxic and biodegradable properties of biodiesel [32].

3. Malaysia's carbon emissions

An UN-commissioned group of scientists known as International Panel on Climate Change (PICC) confirmed that carbon dioxide (CO_2) is the main cause of global warming. There are of course other gasses that can trap more heat than CO_2 does (e.g. methane, nitrous oxide, and chlorofluorocarbons); however these gasses are not comparable with CO_2 in concentration. Consequently, the effect of GHG is understood as the equivalent amount of CO_2. Therefore, APERC has modeled only the emissions from carbon dioxide (CO_2) since the CO_2 emissions from fuel combustion account for over 90% of energy related greenhouse gas emissions (GHG) worldwide on CO_2 equivalent basis, and these energy related emissions in turn account for about two thirds of total greenhouse gas emissions on a CO_2 equivalent basis. The amount of “carbon dioxide equivalent” release in the world from 1990 is 6 billion metric ton, which represents an increase more than 20% [33]. For the first time in man's history, greenhouse gas carbon dioxide in the atmosphere hits the record of 400 parts per million (ppm) [34].

Table 6
Carbon dioxide emissions by region (Million metric tons carbon dioxide) [3].

	2012	%	2035	%
OECD				
Americas	6703.99	20.9	7771.79	18.0
Europe	4114.88	12.8	4257.42	9.9
Asia	2109.64	6.6	2293.74	5.3
Non-OECD				
Europe and Eurasia	2806.33	8.7	2963.86	6.9
Asia	12,184.62	37.9	19,687.73	45.6
Middle East	1805.43	5.6	2658.81	6.2
Africa	1165.13	3.6	1734.75	4.0
Central and South America	1222.71	3.8	1851.69	4.3
Total World	32,112.72	100	43,219.8	100

North America, with emission of 6703.99 million metric ton of the gas in 2012, currently is the second largest producer of CO_2 gas after Asia. Forecasts show that emission of the gases form the source of fossil fuel will increase by 35% in 2035. That is, if no countermeasure is taken to deal with the threat [3]. Carbon dioxide emission due to energy consumption for 2012 and the forecasts for 2035 is listed in Table 6 for different regions.

Fighting the increase of carbon emission is one of the principal reasons of the recent trend toward Renewable Energy solution in Malaysia. As illustrated in Fig. 4, role of fossil fuel in emission of CO_2 in Malaysia has followed an ascending trend since 2000 [35]. Considerable aggregation of the gasses in the atmosphere surely results in intense climate change, acid rain and smog. Furthermore, extraction, processing, and transferring the fossil fuel, by itself, needs a great deal of energy and consequently causes more harmful effects on the world ecology. On the other hand, domestic

economic development is subject to the extent to which energy demands are supplied [36].

Emission of CO_2 in APEC regions is expected to grow about 40% from 2010 (19.0 billion ton) to 2035 (25.1 billion ton). About one half of this amount is emitted by electricity and heat generation utilizations [20]. Among the countries in the regions, Malaysia in the 4th position and after China Taipei, Thailand, and Singapore, emits 191.444 million ton of CO_2 [20,37]. Emission of CO_2 from fuel combustion as reported by Lower Emitting Economies in the APEC region is portrayed in Fig. 5.

In the Copenhagen Climate Change Summit on December 2009, the PM of Malaysia agreed with conditions to initiate reduction of emission of carbon up to 40% in terms of emissions intensity of GDP by 2020 on the basis of statistics of 2005, along with preservation of the forest of the country [33].

Taking into consideration its vast palm oil resources, Malaysia, among some other countries, is a proponent of production and consumption of biodiesel as a replacement for fossil fuel. The country is currently able to produce about 10.2 million tone of biodiesel [38]. As reported by the USA Department of Agricultural Energy, the biodiesel may shorten the life cycle of CO_2 by around 78%. It lessens emission and residuals of incompletely burnt hydrocarbons and carbon monoxide to atmosphere [39].

4. Renewable energies availability and potential in Malaysia

The term "renewable energy" refers to the energy types obtained from a natural process, which does not involve use of delectable resources including fossil fuel and uranium. On the list of renewable energy sources are sunlight, wind, mini hydropower, biomass, geothermal energy. Consumption rate of renewable energy for 2011 is pictured in Fig. 6 [3].

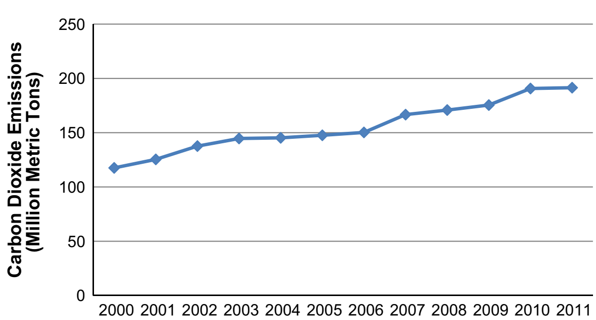


Fig. 4. Total carbon dioxide emissions from fossil fuels in Malaysia [35].

Besides the major energy sources (e.g. natural gas, oil, coal, and hydropower) the Malaysian government has never stopped searching for and examining other possible renewable energy sources. In spite of fast pace of growth of consumption, renewable energy only constitutes 2.1% of world energy usage [5]. Knowing this, dealing with different aspects of renewable energy such as biomass, solar, and mini hydropower in Malaysia is the subject matter of this section [11]. The country has access to immense sources of renewable energies. Although, the country has achieved noticeable results in using such sources of energy, there remains great deal of work to be done before achieving the optimum situation of using renewable energy in Malaysia. Table 7 represents a brief of potentials of renewable energy for power generation in the country [40]. The permanent quest and studies are concentrated on biomass as an alternative fuel.

By adopting a wide range of policies, Malaysia fosters developments in the field of renewable energies. Under the Five-Fuel Policy, renewable energies are in the list of fuel mix for generation

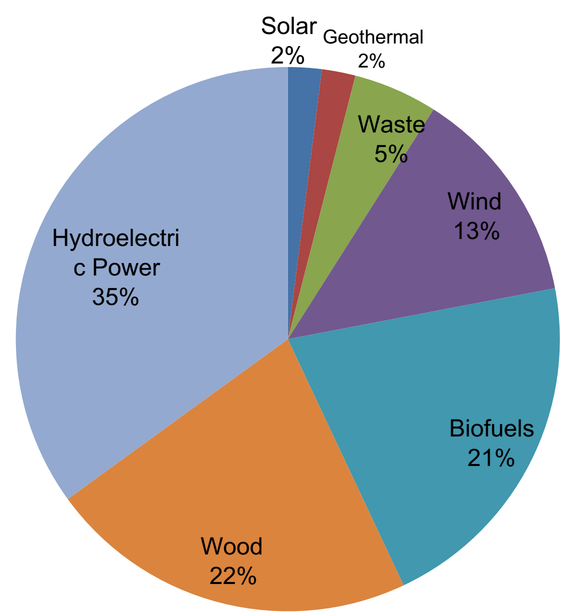
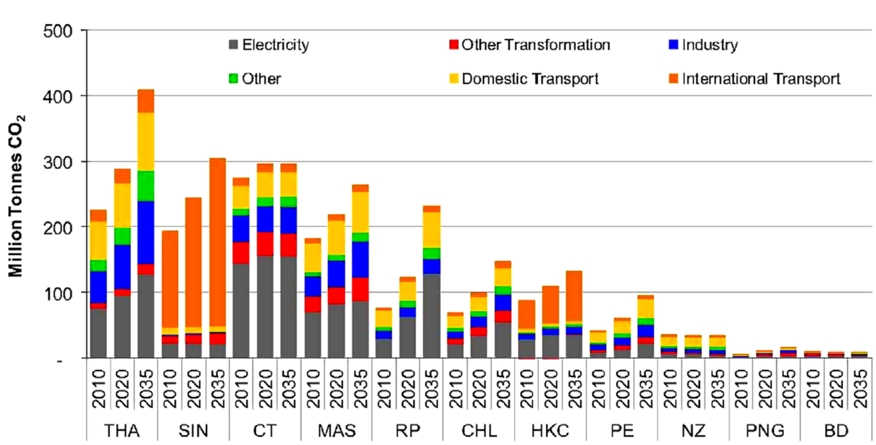


Fig. 6. Renewable Energy Consumption.
Source: [3].



Source: APERC Analysis (2012)

Fig. 5. Carbon dioxide emissions from fossil fuels in Lower Emitting Economies in the APEC region [20].

Table 7
Renewable energy potential in Malaysia [40].

Renewable energy	Potential (MW)
Hydropower	22,000
Mini-hydro	500
Biomass	1300
Municipal solid waste	400
Solar PV	6500

of power following oil, coal, gas, and hydro. The 10th Malaysia Plan sets the target of 985 MW by 2015 for grid-connected generation to be produced by renewable energy sources (i.e. 5.5% of total electricity generation in the country). This volume of energy is supposed to be generated from biomass (330 MW), biogas (100 MW), mini-hydro (290 MW), solar photovoltaic (65 MW) and solid waste (200 MW) sources. The Malaysian state adopted the feed-in-tariff (FiT) in December 2011 for the power obtained from the renewable sources. The FiT is financed by way of a levy charged on the electricity subscribers in the economy. The state also founded a special agency, the Sustainable Energy Development Authority (SEDA), as a subsidiary to the Ministry of Energy, Green Technology, and Water, to handle the FiT fund and foster and motivate developments in the field of renewable energy. It is expected by the government an operational capacity of 3 GQ from new renewable energy by 2020, so that one-third of the energy will be generated from solar photovoltaic and biomass will constitute another one-third of the energy [12].

4.1. Solar

The sun, the unlimited source of energy, theoretically can meet the global energy demand. Out of 3.9×1026 W of energy generated by the sun, 1368 Wm^{-2} reaches the outer atmosphere of the earth. The amount of energy that reaches the earth varies by $\pm$1.7%, which is due to variable distance between earth and the sun [41]. Malaysia receives about 400–600 MJ/m^2 from the sun monthly [42]. Solar energy technology started its development 50 years ago, however, solar powered devices – known as photovoltaic (PV) are still taken as state of the art equipment [43]. A PV system is featured with several solar cells, which are in charge of converting light into sun light. Nowadays, solar energy applications are commonly thought of as household warm water system, water pump, and food drier. The main portion of solar energy in Malaysia is used for domestic purposes and large scale commercial consumption only constitutes a trivial part [44].

There are estimates that solar energy that reaches Malaysia equals four times of global world fossil fuel resources [45]. Currently, there are about 10,000 household warm water systems in Malaysia running by solar energy [44]. The climate suits using solar energy as the country enjoys several sunny days in the year.

Average daily solar energy reaching to Malaysia varies between 4.21 kWh/m^2 and 5.56 kWh/m^2 [46]. The peak of solar energy is estimated to be 6.8 kWh/m^2, which happens in August and November and the minimum level amount is 0.61 kWh/m^2 in December. Because of considerable solar radiation over the year, the north and some places in the east of the country have the maximum capacity for solar systems [47]. Nowadays solar energy consumption in Malaysia reaches 1 MW and there is potential to achieve 6500 MW [48].

4.2. Mini-hydro

Due to low cost, reliability and environment-friendly features, mini-hydropower or small-scale hydropower projects have drawn a great deal of attention all around the world. There is no definite

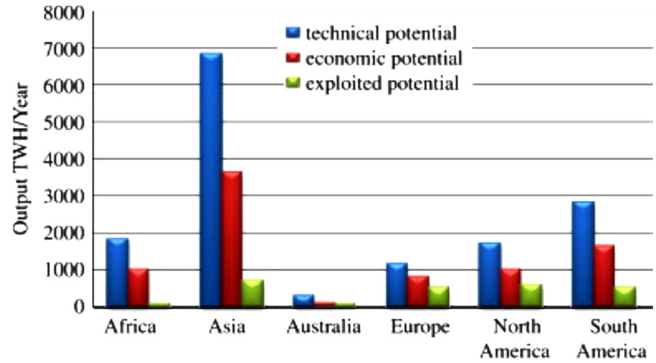


Fig. 7. Exploited hydropotential by continent [51].

definition of small hydro project; however, a maximum of 10 MW energy generation capacity is commonly accepted as the ceiling capacity of a small hydro project [49]. Nowadays, mini-hydro energy sources can be found in almost any country. A view of the present capacity in different continents is depicted in Fig. 7. Clearly, the greatest unrealized capacities still are in Asia, Africa, and South America [50].

Mini hydropower generators experienced a growth rate of 28% in 2005 and global capacity of small hydro capacity reached 85 GW [49]. The largest capacity has been developed in China, which constitutes 59% of world capacity and Japan is in the next in line with 11%. Mini-hydro capacity in the USA, Italy, and Brazil is 8%, 3%, 3% respectively [52].

About 42% of the Malaysian territory comprises highland areas such as Titivangsa, Tahan, Kapuas, Hulu, Crocker, and Brassey. These highlands supply several streams and rivers and give the country high capacity for using hydropower [48,53]. To supply electricity power to remote villages in Sabah and Sarawak, which are located far away from the main electricity grid, the Natural Resources and Environment Ministry has plans to use micro hydroelectric systems [54]. Otherwise, these villages would use diesel generator to supply their electricity demands. The new systems cost less than other convenient ways and produce no pollution. Currently, five mini hydroelectric power plants supply electricity to villages in Sabah and Sarawak. It is noticeable that by converting energy of flowing water into electricity, the power plant generates 10 kW of electricity. These power plants cover their costs easily and save 1000 gallons of diesel each year [55].

Presently, in Malaysia these potential large and mini hydropower are being utilized. The country supplies 6270975.10 GWh of its electricity demands from such plants at different sizes. Around 490 MW potential mini hydropower can be run in the country, while only 43.7 MW has been used in by 2011 [56]. A recent reconnaissance study revealed 28.9 MW capacity for electricity through micro hydropower plant in the west of the country [57]. Currently, 50 kW electricity energy is generated by micro hydro plants in Malaysia with a head of 10 m and water discharge of 1 m^3/s using an induction generator [58]. By July 2009, 30.3 mW mini-hydropower plants were under development to supply 470 MW until 2020 [59].

4.3. Wind and tidal energy

Taking into consideration that wind energy generates no air pollutants or greenhouse gas and that it causes trivial effects on the environment, wind energy is listed in green power technologies list [60]. By wind energy, we refer to converting wind speed into preferred forms of energy including electricity power and mechanical power (e.g. windmills, wind pump or sailing ships) [61]. By the end of 2012, 282,275 MW electricity was generated by

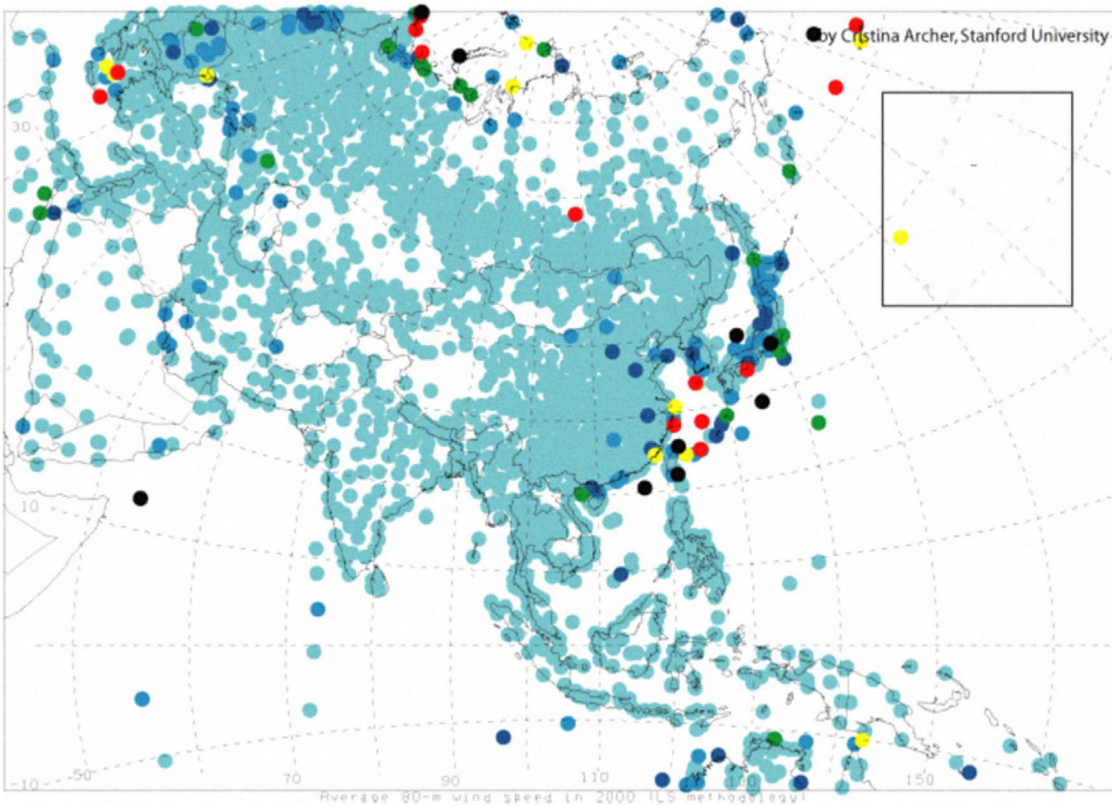


Fig. 8. Wind energy potential for Asia [64].

wind power all around the world [62]. About 280 TWh/annum is generated by wind turbines in the world; this figure is about 3% of the worldwide electricity consumption. Following an average growth of 30% in the past decade, the growth rate showed a considerable decrease during the past 3 years. So that, world growth rate of wind energy production decreased to 19.1% – the lowest of the last two decades [62].

Usage of wind power as a source of energy leads to more development at national level and in coastal area in particular – these areas are featured with continuous wind blow [63]. The potential of wind energy in Malaysia is depicted in Fig. 8, and as shown, Malaysia is at level 1 for which wind blow speed is less than 5.9 m/s [64]. For the offshore area near the country the wind speed in usually less than 5 m/s [65].

Having a wind speed ranging from 2 to 6 m/s, the best option for wind power turbines are small and medium scale turbines (10 and 10–100 kW) [63]. In [66] Malaysia, based on the condition for wind power generation, it was classified as low wind speed wind turbine.

Controlling wind power is feasible only on remote islands of east coast states of Peninsular, Malaysia with wind speed of up to 30 knots or higher during charge of cold air from the north (30 knots = 15.4 m/s or 55 km/h) [67]. Another potential area for wind power generation is the northwest coast of Sabah and Sarawak regions with wind speed of 20 knot or higher. Given that the maximum performance can be obtained between October and March, the power generation site can supply electricity during monsoon season. The Malaysian first ever wind farm was built in Terumbu Layang-Layang Island, Sabah [67].

A study conducted in Universiti Kebangsaan Malaysia in 2005 revealed merits of using 150 kW turbine on the island [67]. In [68] it is suggested that Terumbu Layang-Layang Island has the biggest wind energy potential in comparison with other candidate places in the country. Results of the project commissioned by Malaysia Government and National Electricity Board suggested that about 50% of the household load needs might be supplied by wind farms even if the country has light and unstable wind flow [69].

The possible opportunity to control off-shore energy in Malaysia has been the subject of study since a small effort was made to check for feasibility. Literature review showed that the common categories of available energy include (a) Tidal Energy (b) Current Energy (c) Wave Energy and (d) Thermal Energy [70,71]. Another promising renewable energy source in Malaysia is Tidal energy. The main stream of studies in recent years was exploration of the potential of ocean energy as electricity source in Malaysia [72]. In [73] Pulau Jambangan, Kota Belud and Sibu are listed as the preferred locations with great potential of tidal energy. The total capacity of electricity power is around 14.5 GWh/yr. Lee and Seng [72] showed that Barrage approach has 6 sites (Sejingkat; Pelabuhan Kelang; Pulau Langkawi; Tawau; Kukup; and Johor Baru) across east and west Malaysia, which represents availability around 76.16–63.33% of the time. Using a single turbine with a 5 m long blade at the site with the highest potential, Sejingkat, 14.970 kWh of energy can be obtained on a monthly bases. In general, a single household in Malaysia uses around 350 kWh/month [69]. Because of this, evidently the electricity power generated by a single turbine with 5 m blade is enough to supply 42 households.

4.4. Biomass

One of the sources of renewable energy is biomass, which is known for its high potential to meet the energy requirement of a contemporary society – whether developing or industrialized [74]. Biomass means non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by-products, residues and waste from agriculture, forestry and related industries as well as the

non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material [75]. Nowadays, households and industries consume considerable volumes of fuel wood, farming products and residues, empty fruit bunches, animal wastes, and leaves [76].

By "first-generation biofuels" we point out fuels extracted from farming products (food or feed) and new oilseeds including jatropha and pongamia. There has been a complete technological development for extracting fuels out of these resources [77,78]. Presently, ethanol (type of alcohol) extracted from sugarcane and biodiesel (type of ester) extracted from oils or fats are two most used types of biofuel. Moreover, the biofuels obtained from sources that are not actually farmed for food is known as the 2nd generation of biofuel (also known as cellulosic). Enormous volumes of woody biomass (e.g. agricultural and forest wastes and residues and urban solid wastes) are used by cellulosic technologies to produce energy [79]. Finally, the 3rd generation of biofuels is extracted from feedstock. This fuel is characterized with more longevity and presently the main reliable sources are microalgae and photosynthetic microorganisms (diameter < 0.4). These sources used sun light, CO_2, and water to produce algal biomass [80].

Biomass energy represents about 10–15% (45 exajoule, EJ) of the global energy consumption [74]. It is one of the key sources of energy in the majority of Asian countries. Many Asian countries – Malaysia included – have set targets for using biomass-based fuels as an alternative renewable fuel [81]. Each day, capacity of global production of biofuels is raised by 0.7%, which is equal to 10,000 barrel per day oil equivalent (b/doe) however, this is the lowest growth rate since 2000 [5]. Currently, there are 5 types of bio-fuels using biomass as the source: bio-ethanol, bio-methanol, bio-briquettes, hydrogen gas and pyrolysis oil [82]. Only biodiesel and bioethanol are presently produced as a fuel on an industrial scale [83]. Biodiesel is the renewable energy mainly derived from vegetable oils or animal and holds great promise to replace petroleum-derived diesel in compression ignition (CI) engine [76].

A biodiesel fuel blend (B5) was officially introduced by National Biofuel Policy (2005) in late 2009. As stated by Pusat Tenaga Malaysia, PTM (Malaysia Energy Centre), the Malaysian state shall enforce biodiesel B5 standards and the new fuel, which will be available at selected gas stations. The main source of the fuel is planned to be oil palm residues including empty fruit bunches (EFB), shells, and fibers [84]. The estimated volume of emitted CO_2 is about 40,000–50,000 tons/yr [85]. To keep its competitive advantages over petroleum-derived diesel, there is a need to have continuous inflow of feedstock at a reasonable price. The feedstock is needed to have high oil content, suitable fatty acid composition, be easily farmed (little need for water, fertilizer, soil, and pesticides), have adjustable growth rate and harvest season, be consistency in maturity rate of the seeds and have reliable markets for the by-products [86].

Malaysia is 32.90 million ha in extent, 20.1 million ha (61%) is covered with natural forest and 4.89 million ha (14.9%) is dedicated to farms [87]. The major agricultural crops grown in Malaysia are rubber (39.67%), oil palm (34.56%), rice (12.68%), cocoa (6.75%) and coconut (6.34%).

Taking into consideration that 67% of farm lands are used for farming oil palm tree, the biomass obtained from oil palm tree is a highly reliable source. Presently, 85.5% of biomass materials are obtained from oil palm industry. The mass is comprises empty fruit bunches, fibers, shells, and palm trunks. Thanks to its calorific value, oil palm holds great promise as the source of alternative energy. Malaysia has undertaken to minimize emission of CO_2 through sustainable development along with implementing sustainable farming methods to preserve the rainforests and wildlife [88].

Table 8
Top 10 countries in terms of absolute biodiesel production [89,21].

No.	Country	Volume (million liters)	Production cost ($/L)
1	Malaysia	14,540	$0.53
2	Indonesia	7595	$0.49
3	Argentina	5255	$0.62
4	USA	3212	$0.70
5	Brazil	2567	$0.62
6	Netherlands	2496	$0.75
7	Germany	2024	$0.79
8	Philippines	1234	$0.53
9	Belgium	1213	$0.78
10	Spain	1073	$1.71

The 10 leading producers of biodiesel are listed in Table 8. Clearly, Malaysia is far ahead of the other countries in the list [89]. Malaysia's richness in oil palm is the primary driving force for its development in the biodiesel industry. Thus, Malaysian industries do not need to import raw materials for further development. In addition, independence in supplying the raw materials gives the producers of biodiesels in Malaysia the power to control cost and quality more effectively [32]. This means that the country, with considerable oil palm resource, has enough reasons to support industrial scale production and utilization of biodiesel as a replacement for fossil fuels.

As the leading producer of palm oil, Malaysia runs about 362 palm oil mills that process 71.3 million tons of fresh fruit bunch annually to produce about 19 million tons of crop waste mainly consisted of empty fruit bunch, fiber, and sell [90].

Currently, Malaysia has an estimated capacity of 10.2 million tons of biodiesel [38]. In late 2011, more than 20 biodiesel plants were running in Malaysia that constituted annual capacity of 2.62 million ton [91].

The efficiency of energy obtained from oil palm biomass is 50% or 8 Mtoe, which means saving RM7.5 billion of crude oil each year. Out of 4.3 million ha of oil palm farms in Malaysia, 50–70 ton of biomass residues were obtained from each hectare in 2007. There are other farming wastes such as bagasse, sugarcane, rice husks, and wood residues that can be used along with oil palm residues [92–94]. As of July 2009, 39 MWcapacity for energy generation is under construction and it is estimated to reach 1340 MW by 2030 [48].

4.4.1. *Municipal solid waste and biogas*

Solid waste management, by definition, is a discipline to manage handling and disposal of solid waste. In spite of significant economic development in Malaysia, development in solid waste management is not comparable with other sectors. The country, waste minimization program, still tries to meet the criteria of the UN Agenda 21 regarding control strategy [95].

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including Incineration, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE) [96]. Biogas production, in Malaysia, is mainly through anaerobic conditions with the use of waste management facilities. The major sources are city landfill, anaerobic ponds of Palm Oil Mill Effluent (POME), other industries and farming facilities. The amount of energy extractable from biogas is a factor of content of methane in the gas. A study on the Clean Development Mechanism (CDM) potential in the waste sectors, revealed that the main portion of the potential lies in the anaerobic degradation process in the landfill and POME ponds [48,92–94,97].

Table 9
Power and heat potential from CDM projects waste sectors [48,92–94,97].

Waste sectors (mT/yr)	Methane recovery potential (mT/yr)	Total technical power potential (MW)	Feasible total[a] installed capacity (MW)
MSW landfill	176,000	173	45
Palm Oil Processing[b] (POME)	245,000	330	160
Swine farming[c]	35,500	46	23
Other industries[d] (wastewater)	8000	35	7
Sewage	Negligible	Negligible	Negligible

[a] Total installed capacity is derived based on the power plant operation of 80% capacity factor i.e. 7008 h/yr. Feasible projects based on ROE higher than 15% and attractive with CDM financing.
[b] For POME, gas engine cogen which produces power and heat is the technology base. The power efficiency of gas engine cogen is assumed at 30% where else thermal efficiency at 50%.
[c] When heat is not necessary, power generation only by gas engine is base where the power efficiency is 40%.
[d] Power/heat generation is calculated based on the heating value of methane (55.4 GJ/ton). Where, methane potential × heating value × power/thermal efficiency × MJ kWh conversion factor (0.278).

Development of economy puts more demand on energy sectors and results in changes in energy consumption pattern. This, consequently, forces the government to find new energy sources to meet the demand. At any rate, urbanization results in more wastes and the government may find in the waste management the answer for more demand of energy in the future [23,25]. Solid wastes in Malaysia can be divided into commercial, domestic, industrial, construction, and municipal wastes [98]. Urban solid waste – household, industrial, and commercial wastes – constitutes 98% of total waste in Malaysia. The waste has the capacity for generating landfill gas (LFG) consisting of methane (CH4), CO_2, and greenhouse gases (GHG) [99]. The gas suits power generation, transportation, and food industries purposes perfectly. Presently, the country runs 261 landfill sites [40]. Table 9 lists the potential sizes of recovery, the pertinent potential power, and potential heat for practical projects. A total capacity of 4.45 MW was under construction in July 2009 and the forecasted potential of biogas by 2028 is estimated to be 410 MW [48,92–94,97]. In 2010, the country generated 1.9 × 109 kWh energy from biogas, which constitutes 1.5% of national energy consumption or the power needed by 420,000 citizens [100].

Each Malaysian citizen in cities produces 0.5–08 kg of waste on average, and this figure for the city Kuala Lumpur (the capital) has reached 1.7 kg, so that every day the city produces 2500 ton of waste [101]. Results of a study showed that, organic waste constitutes 57% of the MSW produced by the capital city which hints a considerable capacity for extracting energy [59]. The main method for disposing of the waste is landfill; however large cities choose to incinerate the waste. The calorific content of MSW in Malaysia varies between 1500 and 2600 kcal/kg which promises 640 kW/day of energy from incineration facilities with daily capacity of 1500 ton with average calorific value of 2200 kcal/kg [98,102].

Malaysians produced 8.196 million ton of solid waste in 2010. With growing population, economy, and industrialization, this figure follows an ascending trend. Estimates say that MSW of the country will hit 9.82 million ton/yr by 2020 [82,103]. The potential energy extractable from solid waste by 2022 will reach 360 MW [48].

5. Palm oil biodiesel and Malaysia

Biodiesel production, for Malaysia, stands for palm oil. As a nutritious vegetable oil, palm oil is used commonly for cooking. It is extracted from palm tree, the tree which perfectly suits the Malaysian climate. The tree is a native species of West Africa [90], and was brought to Malaysia as an ornamental tree in 1870. The area covered with palm tree has increased from 1.5 million ha in 1960 to 4.917 million in 2011 [105]. Located in the tropical South East Asia, air temperature in Malaysia barely changes as the country enjoys an equatorial climate. On average the country has 200–250 cm precipitation [106]. The geographical location and annual precipitation make the country perfect for plant growth, and consequently the county may rely on biofuel as the best source of energy. Add to this, the immense jungle areas and the fact that agriculture is the largest sector of the national economy [107].

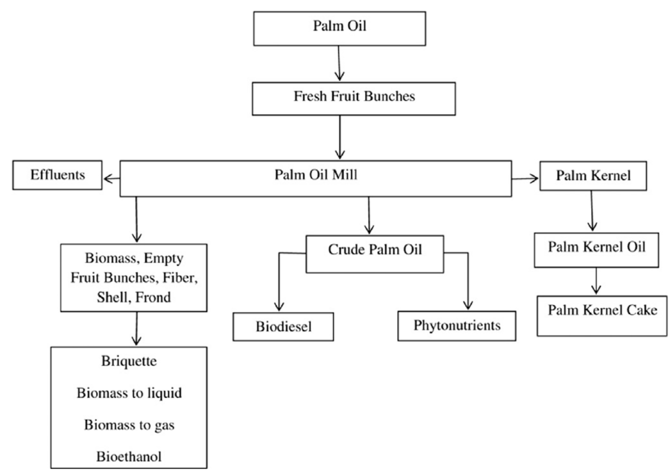


Fig. 9. The potential sources of renewable energy from palm oil [109].

Malaysia has gradually increased its capacity for producing palm oil from 4.1 million ton to 6.1 million ton between 1985 and 1990; this figure reached 16.9 million ton in 2010 and 18.9 million ton in 2011. Speculations say that this capacity will reach 19.4 in 2012. The palm oil industry perfectly covers domestic needs for oil and fat and even has developed capacities for export [105]. The country supplies 41% of the world palm oil, and it is the largest exporter of palm oil with capacity of 14.21 million metric ton, which is about one half of the world export of the oil. Taking into consideration that the country is a leading supplier of palm oil and the products in the world, Malaysia fills in a pivotal role to meet the international market demand for oil and fats [108]. Evidence shows the considerable potential of palm oil as an alternative renewable energy source; this is portrayed in Fig. 9 [109].

The internal wall of the fruit, known as "Mesocarp", is fleshy, and through processing, palm oil is extracted from it. First, crude palm oil (CPO) is obtained from the mesocrap by way of refining and kernel processing. The obtainable palm oil from CPO is a factor depending on the type of tree and its age. About 25–28% of CPO is constituted by extractable oil. The oil obtained from the palm trees is called CPO. The untreated oil needs further processing in the

Table 10
Oil productivity of major oil crops [105,110].

Oil crop	Oil production (million tons)	Total production (%)	Average oil yield (tons/ha/yr)	Planted area (million ha)	Total area (%)
Soybean	41.62	23.2	0.40	103.84	40.9
Sunflower	13.9	7.3	0.55	23.87	9.4
Rapeseed	23.68	13.2	0.72	33.01	13.0
Palm oil	56.15	31.3	4.14	13.46	5.3
Cottonseed	4.84	2.7		33.52	13.2
Others	40.00	22.3	–	46.20	18.2
Total	179.38	100	–	253.9	100

refinery before being suitable for converting into methyl ester and being used as biodiesel. The biodiesel may be further processed into methyl ester or Envo which is a mixture with petroleum diesel at specific proportion [16].

Taking into account the covered land by palm tree farms, the crop is one of the efficient choices for oil production. Comparing with other oilseeds, one hectare of palm tree produces 8 times more oil. On average, about 4.14 ton/yr of oil is obtained from one hectare of palm tree; a comparison of oil capacity among rapeseed, sunflower seed and soybean is presented in Table 10 [105,110]. Presently, the common palm tree planted in the country is Tenera hybrid, which produces 4.14 ton/yr of oil per hectare along with 0.5 ton of palm kernel oil and 0.6 ton palm kernel cake. The useful life of oil palm is about 25 years and crop can be harvested 30 months after planting. From 1.3 million ton in 1999, production of palm kernel oil hit 4.7 million ton in 2011. Before 1970, the majority of the palm kernel was exported; however, production of unprocessed palm kernel oil and palm kernel cake was triggered in 1979 [105].

As mentioned above, production yield of palm oil is much higher than other alternatives, while it needs less fertilizer, water, and pesticide. It also needs less sunlight, which means the plant needs less sun energy to grow; thus, more oil is yielded per hectare. Crude and refined palm oil are at the top of the list of best sellers in the international market.

The contribution of the domestic palm oil industry in Malaysia export was MYR65.2 billion in 2008; this hints at the considerable role of the industry in the national economy. In terms of value, the import of palm oil by the EU corresponds with 4.9 milion ha of soybeans or 1.7 milion ha of rapeseed [111].

Palm oil export constitutes about 26% of the national export of fat and oils by Malaysia. The products are exported to around 150 states in the form of a variety of products. Totally, 233 million ha of land is used for farming palm oil all around the world. The country is running projects to improve productivity of the industry, so that there are programs to increase oil yield through genome sequencing method. The purpose of the method is to improve average oil production performance in a hectare from 4 ton to 8 ton. Genome sequencing method is a laboratory course of action to obtain the whole DNA sequence of an organism [112]. The technique makes it possible to exercise scientific process and procedure on palm oil plant for higher yield. The country hopes that the technique will help her to keep her position in the global market of palm by meeting the demands with no need for dedicating more area of land to palm tree farm.

Palm oil has won the position of the world's second most used oil since 1985 while the first position is kept by soybean oil. Malaysia's share in global production has decreased from 51% to 38% between 1999 and 2011. Palm oil constitutes the major portion of international trade of oil. Malaysia possessed 46% of 39.04 million ton-international market of palm oil in 2011. The country has made the most impressive progress in the market between 1974 and 1999 so that exports of processed palm oil increased from 0.9 to 8.9 million tons. The country hit 17.99 million tons export of the oil in 2011; this figure for the previous year was 16.66 million tons. [105]. The major destinations of Malaysian palm oil export are China, Pakistan, the European Union, India and the United States [113]. The industry created jobs for 471,000 Malaysian workers in 2012 [114]. The results of lifecycle analysis (LCA) on different types of biodiesels showed that the biodiesel extracted from palm oil, comparing with that of soybean, may attenuate production of GHC by 62%; this figure comparing with the biodiesel from rapeseed and sunflower are 45% and 58% respectively [115].

Recent scientific discoveries have illustrated that oil palm plantations are more efficient "carbon sink" than rainforests. The term carbon sink refers to an area of dry mass which can absorb harmful greenhouse gasses including CO_2. There are reports that every hectare of palm plantation assimilates up to 64.5 tons of CO_2 every year, while this figure for original rainforest is only 42.2. Moreover, expansion of new palm tree farms does not necessarily mean destroying forest and biodiversity when the new plantations are developed in other farms such as cocoa, rubber, and coconut for better economic revenue. The whole process starting from harvesting up to production of the oil and other by-products (oil palm biomass included) are conducted in observance of best management practice (BMP). The term BMP refers to methods and procedures that are environment friendly including no burning operation, wildlife conservation, integrated post management (IPM), minimization of waste, and the utilizations that result in helping sustainable development of oil palm plantation and production in the country [116].

6. Biodiesel production technology

Vegetable oils and fats can be processed into biodiesel in three main ways; base catalyzed transesterification of the oil, direct acid catalyzed transesterification of the oil, and oil to its fatty acid conversion and then biodiesel [117]. The second option is the most commercially used method thanks to the low temperature, low pressure, and high yield of the process [118]. The combination of mono-alkyl esters from a long chain of fatty acid (FAMEs) – obtained from plant oils or animal fats – constitute the biodiesel fuel [4]. Transesterification (alcoholysis) is highly recommended for production of biodiesel [119–121]. It is actually a chemical reaction between triglycerides and alcohol with alkaline liquid acting as the catalyst; sodium or potassium methoxide is commonly used to obtain monoesters of fatty acid. As shown in Fig. 10, the long and branched chain triglyceride molecules are converted into monoesters and glycerin [122]. From practical and chemical viewpoints, every vegetable oil may be used for biodiesel production. However, there are factors such as availability of the raw

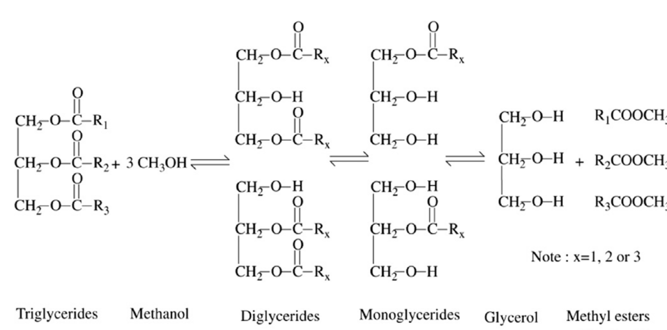


Fig. 10. General representation of the catalytic transesterification process of triglycerides with methanol to produce biodiesel [122].

materials, other usages, productivity, and in some cases, socio-economic influences [32].

One of the best substitutes of diesel for compression-ignition (CI) engines that imposes no engine modification is FAME [36]. Thanks to its almost identical characteristics to petroleum, among many, palm methyl ester (PME) is known as one of the best alternative fuels [123]. In some cases, PME has been used in diesel engine as fuel and excellent combustion performance has been obtained [124–129]. However, the greatest drawback of PME as engine fuel is necessity for high purity [130].

It is noticeable that vegetable oils in many cases are a mixture of several fatty acids, and reasonably, they determine the properties of the oil and obtained biodiesel. In extraction of biodiesel, palm oil is the main raw material. Palm oil comes from palmitoletic acid (16 carbon saturated acid), which is found in the chemical structure of palm oil [109].

The method (transesterification) is featured with a high conversion rate of 98%, minimal side effects and fast reaction. Taking into consideration that no intermediate compound is needed and the oil-biodiesel conversion can be conducted directly, the advantages of the method are undeniable [131]. The chemical equation in Fig. 10 represents the conversion of palm oil into biodiesel and glycerin. The fatty acids connected to the glycerin dictate the properties of the fat [118]. In addition, glycerin which is considered as a co-product, may add to the value of biodiesel [132].

The equation in Fig. 10 shows that glycerin and biodiesel are obtained as the output of the reaction between palm oil and short chain of alcohol including methanol or ethanol – marked by ROH in the figure. For instance, 10 kg of glycerin and 100 kg of biodiesel is the resultant of reaction between 100 kg of palm oil and 10 kg of alcohol. The role of alcohol is to accelerate the process of conversion. R1, R2 and R3 in the figure above represents the fatty acid chains of the palmitic oil or fat [117].

High boiling point and high viscosity of palm result in deposition of carbon inside the engine and consequently shortens the longevity of the engine that uses crude palm oil. Moreover, in engines that burn crude palm oil, plugging and gumming of filter, pipe lines and injectors are unavoidable, which is because of natural gums (phosphatides) in the oil. However, processing vegetable oils (e.g. palm oil) into biodiesel (methyl or ethyl esters) makes complete combustion achievable. Add to this the heating value of biodiesel which is slightly higher than that of vegetable oil [133].

7. Advantages of palm oil biodiesel for Malaysia

Malaysia has enjoyed considerable social, technological, environmental, and economic advantages thanks to palm oil biodiesel [134]. The biodiesel extracted from palm also lessens the need for importing petroleum diesel, which also saves the limited foreign currency reserves of the country. Moreover, less consumption of fossil fuel means less emission of greenhouse gasses, which consequently decelerates global warming. It is noticeable that the transportation section emits the main portion of greenhouse gases [32]. Therefore, by replacing palm oil biodiesel with fossil fuels in car engines, the whole world will enjoy more benefits. Palm oil biodiesel as engine fuel produces less gases, although, some studies have shown a great deal of NO_x emission resulting from combustion of biodiesel [36]. Comparing with Jatropha and other biodiesel feedstock, palm oil is featured with more oxidation stability. The problem of considerable emission of NO_x from palm biodiesel can be attenuated up to 80–90% by using catalyst converters in the engines [135].Using palm oil as the raw material is the source of another advantage of palm oil biodiesel, which is its sustainability as renewable energy. On the other hand, we have been faced with depleting resources of fossil fuels, which are not renewable. The palm oil is supplied easily by replanting the seeds of the plant [136].

The next advantage of development of oil biodiesel industry for Malaysia is the technological development. By introducing winter grade biodiesel, which suits application in countries with low pour point, the palm oil biodiesel industry has become a pioneer technology. Comparing with fossil fuels, palm oil biodiesel is cheaper. The fact that palm oil biofuel is biodegradable means that it is safer for transportation as any leakage to the nature can be cleaned up at lower costs comparing with fossil fuel [136].The growing demand for palm biodiesel means more demand for palm oil. As a result of increase in palm oil price, palm oil and the related industries find more sources for development. Furthermore, the national economy of Malaysia will enjoy the benefits of development of new markets whether local or overseas [137].

Comparing with other oil crops, cost of producing palm oil is the lowest; in this regard, next in line is soybean which is 20% costlier [138]. Consequently, as the data of the commodity market show, cost of palm oil biodiesel is less than that of soybean oil or rapeseed as shown in Table 11 [88].

Throughout the process of photosynthesis to develop biomass of other parts of the plant, the palm trees, which are the source of palm oil, absorb considerable amount of CO_2. The tree keeps taking CO_2 from the air during its 25–30 years life [88]. The perennial crop also releases enormous volume of O_2 to the air, which is way beyond that by other annual crops such as soybean and rapeseed. In addition, palm tree farms are in fact artificial green forests that produce timber and fiber as well. The tree also helps diversity of the regions to a great extent as it is similar to the native forests in different ways.

On one hand, in comparison with soybean and rapeseed oil, the biodiesel extracted from palm oil is found to have better quality in many respects. The differences lie in the fact that palm oil biodiesel has higher rate of molecular saturation, and therefore, it has fewer number of double bonds in the molecules. This property also results in higher ignition quality in CI engine. On the other hand, this increases cloud point of the biodiesel

Table 11
Price comparison of biodiesel from different feedstocks [88].

Feedstock	Price of crude vegetable oil (USD/tons)	Price of B100 biodiesel (USD/tons)
Rapeseed[a]	815–829 (Ex-Dutch Mill)	940–965 (FOB NWE)
Soybean[a]	735 (FOB Rosario)	800–805 (FOB Rosario)
Palm oil[a]	610 (Del. Malaysia)	720–750 (FOB SE Asia)
Waste cooking oil[b]	360	600 (Estimated)
Animal tallow[b]	245	500 (Estimated)
Jatropha[c]	N/A	400–500 (Estimated)

[a] *Source*: Kingsman.
[b] *Source*: Rice.
[c] Source: Goldman Sachs.

and consequently makes it unsuitable for colder weather. To deal with this problem, specific cold flow additive can be used [86]. Palm oil biodiesel has also caused many controversial problems; among them, fuel and food debate [139,140] and deforestation of rainforests [116] are two issues to name. Still, palm oil biodiesel seems to be prosperous. The enormous demand in other countries mainly in Europe ensures continuous demand and good market for palm oil biodiesel production in Malaysia.

Through cutting dependency on petrodiesel and moving toward agricultural industry, palm oil biodiesel promises energy security, environment preservation and rural development for Malaysia [141]. From the social viewpoint, palm biodiesel holds advantages such as job opportunity and social development for the villages as the population will play key role in the production of palm biodiesel. The industry also improves life standards for many people in the rural area that work in palm tree farms.

8. Conclusion

The enormous growth of demand for fuel in the transportation sector and intensification of environmental concerns have added to worries about limited crude oil reserves, which have resulted in more emphasis on necessity of renewable energy. One of the choices, with many capacities, is biodiesel as a renewable fuel, which has drawn considerable attention recently along with the development of production capacity. Continuous development of biodiesel industries has been guaranteed by renewable fuel policy (mandates, tax, incentives, and subsidies). It is expected that the capacity of biodiesel production will hit 12 billion gallons by 2020.

Global warning and shrinking fossil fuels along with increasing price of oil has convinced the government of Malaysia to pay more attention to renewable energy, which has now become a key element in the movement toward energy diversification. The Malaysian economy is fast developing and its dependency to energy sources in not negligible. There are expectations of 6–8% increase in energy demand in Malaysia each year. Energy security and environment are the two main reasons for explorations for alternative energy. Although, the country is presently one of the main producers and exporters of palm oil, its energy sector is considerably dependent on nonrenewable fuels such as fossil fuels and natural gas.

Adopting new strategies and a variety of programs show that the Malaysian government has come to understand how important renewable energy is. Clearly, the country may act as one of the main suppliers of biodiesel thanks to its vast capacity of palm oil production. It is necessary for the country to take measures to reduce its dependency on nonrenewable energy sources and utilize its enormous capacity for renewable energy like biodiesel. Taking into consideration that around 76% of the country's land is covered by dense tropical forests and farm, Malaysia can rely on biodiesel as a reliable substitute for fossil fuel. The fuel is environment-friendly and can replace diesel fuel with no need for modifying the engine. The country must use its advantages in biodiesel industry to achieve a leading position in the world biodiesel market.

An efficiently developed biodiesel industry surely can be viable from the economic viewpoint, appropriate for the environment, and beneficial for the society. Moreover, the country can expect several benefits by taking the leading position in the world biodiesel market. In addition to considerable export capacities, employment chances, by being among the top suppliers of biodiesel, the country indicates its capacities and merits to become a developed country. Investment in research on palm oil production, improvement of biodiesel, achieving more efficient combustion properties, energy conversion and environmental considerations are of the highest priority for Malaysian state. Based on the discussion above, the country must be able to take the position as the first producer of biodiesel of the world by 2050, which depends on adopting proper management policies and methods. Thus, with the help of comprehensive policies supported by political and social forces, Malaysia can emerge as one of the main producers of renewable and sustainable energy of the world.

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